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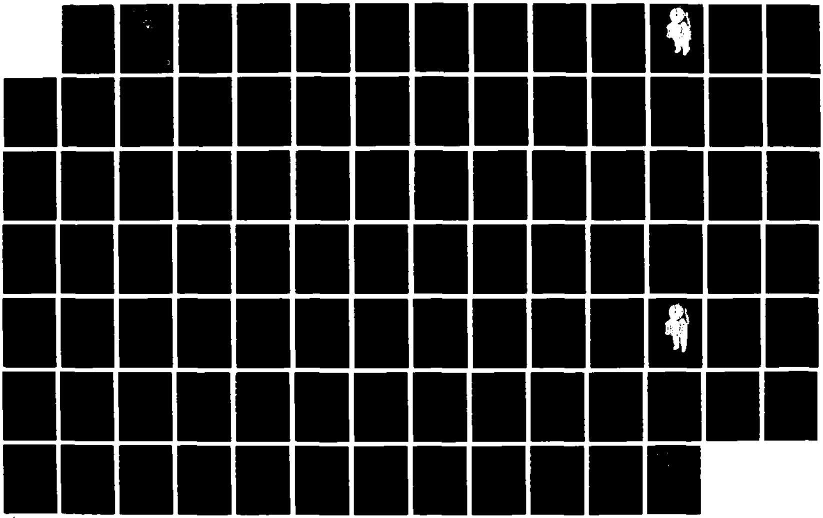

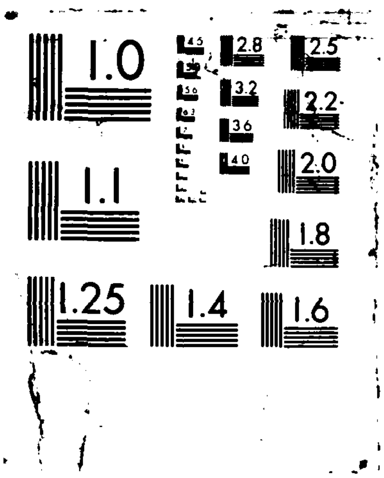
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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

LOGISTIC SUPPORT
FOR THE
NAVY ONE-MAN ONE-ATMOSPHERE DIVING SYSTEM
(NOMOADS)

by

Michael P. Smith

December 1987

Thesis Co-Advisor: Thomas P. Moore

Thesis Co-Advisor: Raymond W. Smith

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This thesis examines the logistic support requirements of the Navy One-Man One-Atmosphere Diving System (NOMOADS). The introductory chapter provides a system description as well as the objectives and methods of the study. Next, a background chapter describes the acquisition and contracting aspects of NOMOADS. The main concern of the thesis is brought forth in the logistics chapter, which considers the concepts of reliability, maintainability, availability, spare parts requirements, and life cycle cost. The final chapter provides conclusions and recommendations. A Draft Integrated Logistics Support Plan (ILSP) is presented in Appendix A.

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Logistic Support for the Navy One-Man One-Atmosphere Diving System (NOMOADS)

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

This thesis examines the logistic support requirements of the Navy One-Man One-Atmosphere Diving System (NOMOADS). The introductory chapter provides a system description as well as the objectives and methods of the study. Next, a background chapter describes the acquisition and contracting aspects of NOMOADS. The main concern of the thesis is brought forth in the logistics chapter, which considers the concepts of reliability, maintainability, availability, spare parts requirements, and life cycle cost. The final chapter provides conclusions and recommendations. A Draft Integrated Logistics Support Plan (ILSP) is presented in Appendix A.

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I. INTRODUCTION

A. DESCRIPTION

The Navy One-Man One-Atmosphere Diving System (NOMOADS), pictured in Figure 1, is a modification of a commercial diving system called "JIM". JIM has been used safely and successfully since 1972 in a variety of underwater tasks including inspection of offshore drilling equipment, location and recovery of anchor chains, bottom searches, emergency recovery of a diving bell during which JIM was mobilized and completed two dives within 24 hours, and still photography [Ref. 1:pp. 5-8]. Potential mission areas for NOMOADS include search, location, recovery, salvage, rescue work, underwater construction, explosive ordnance disposal, and saturation diving support [Ref. 2].

The deepest open-sea scientific dive ever made in a JIM suit was made to a depth of 1250 FSW (feet of salt water) off Oahu, Hawaii on September 19, 1979 by marine scientist Dr. Sylvia A. Earle. The dive and the JIM system were well-publicized by the National Geographic Society. [Ref. 3:pp. 228-243]

NOMOADS is different from JIM in that NOMOADS is being constructed with a torso made of carbon fiber reinforced plastic (CFRP). The Navy hopes that this material will prove lighter and stronger than the magnesium alloy which

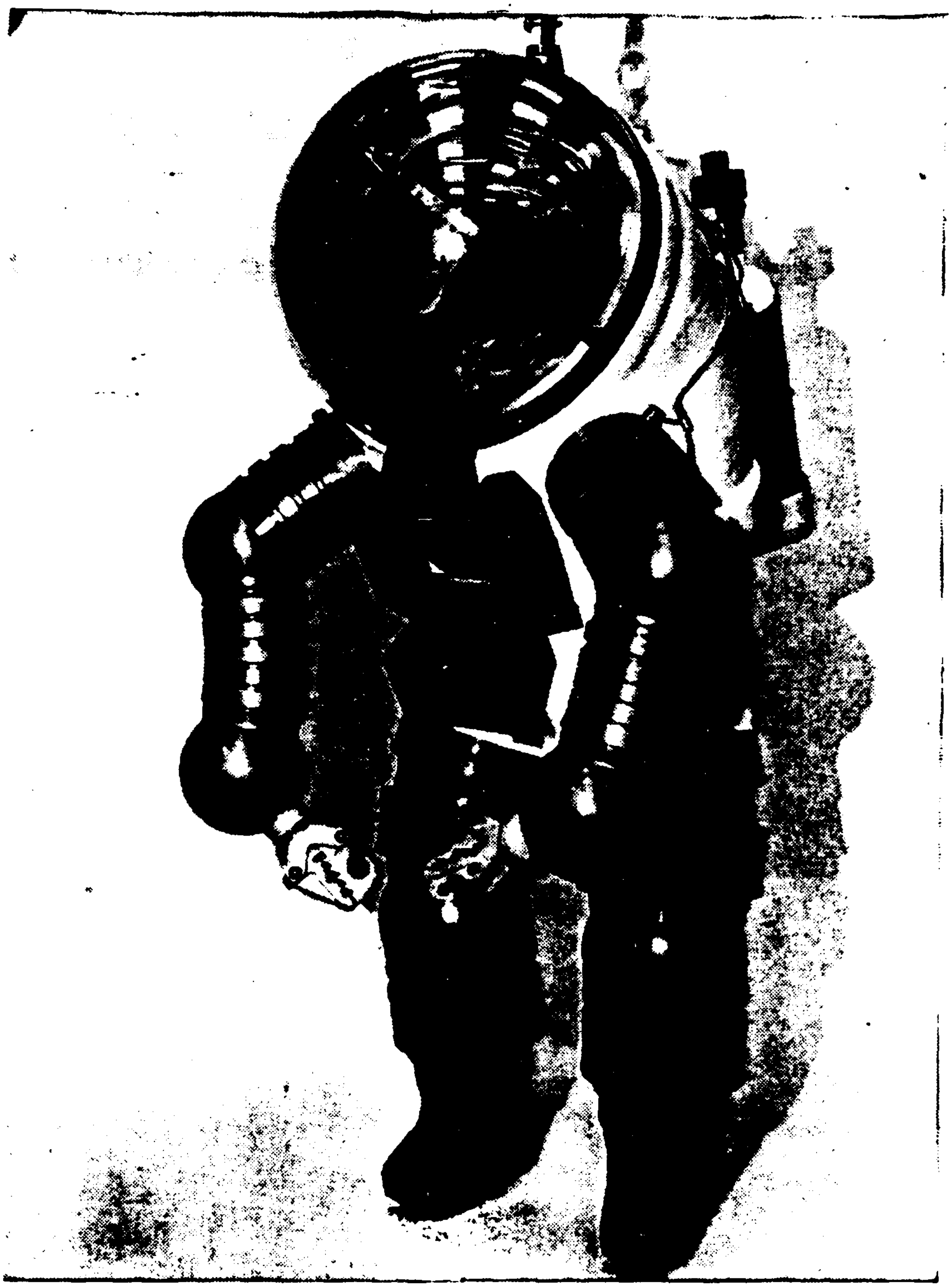

Figure 1

Navy One-Man One-Atmosphere Diving System (NOMOADS)

(Courtesy Slingsby Engineering Limited)

has been used in the torsos of the JIM suits manufactured for the commercial diving industry. The CFRP torso is undergoing extensive testing and evaluation at the Naval Coastal Systems Center in Panama City, Florida for use in deep submergence systems. The NOMOADS deep submergence pressure hull must meet the Navy's system certification requirements for manned, non-combatant submersibles.

NOMOADS has a maximum depth capability of 2000 FSW and a maximum bottom time of 40 hours. The main benefit of using NOMOADS instead of other available diving systems is that it is a one-atmosphere system. This means that decompression is not required. NOMOADS can return to the surface from 1000 FSW in about ten minutes, whereas a saturation diver would require over nine days of decompression to return from that depth. The capability of being able to put a diver on the bottom at great depth quickly and then return him (her) to the surface quickly and safely, with no risk of decompression sickness, is a significant advantage. The operator can walk along the ocean bottom and use manipulators on the arms to do a variety of tasks. The system can be deployed from ships and shore stations or delivered by aircraft to any part of the world in the event of an emergency. No special physical conditioning or extensive diving experience is required to operate NOMOADS. Therefore, technical experts in fields other than diving can be placed in the deep ocean.

NOMOADS is an Acquisition Category (ACAT) IVT program with an estimated life cycle cost of $12,775,000. The program management office is located at the Naval Sea Systems Command (Code PMS395) in Washington, D.C. The Project Engineer and his staff are located at the Naval Coastal Systems Center in Panama City, Florida. As shown in Figure 2, NOMOADS is now in the Demonstration and Validation (D&V) phase of the acquisition process. Current program management efforts are being concentrated on the testing and evaluation of the carbon fiber torso.

NOMOADS research and development (R&D) work is being conducted at the Naval Coastal Systems Center in Panama City, Florida. Also located in Panama City are the Navy Experimental Diving Unit (NEDU) and the Naval Diving and Salvage Training Center (NDSTC). This center of diving expertise is proving to be an excellent location for NOMOADS project development.

An excellent history of NOMOADS development from earlier diving systems is contained in a research study completed by Dr. Arthur J. Bachrach in December, 1981. [Ref. 1]

B. MAJOR SYSTEM COMPONENTS

This section of the thesis describes the nine major system components which comprise NOMOADS, and provides a brief explanation of each component.

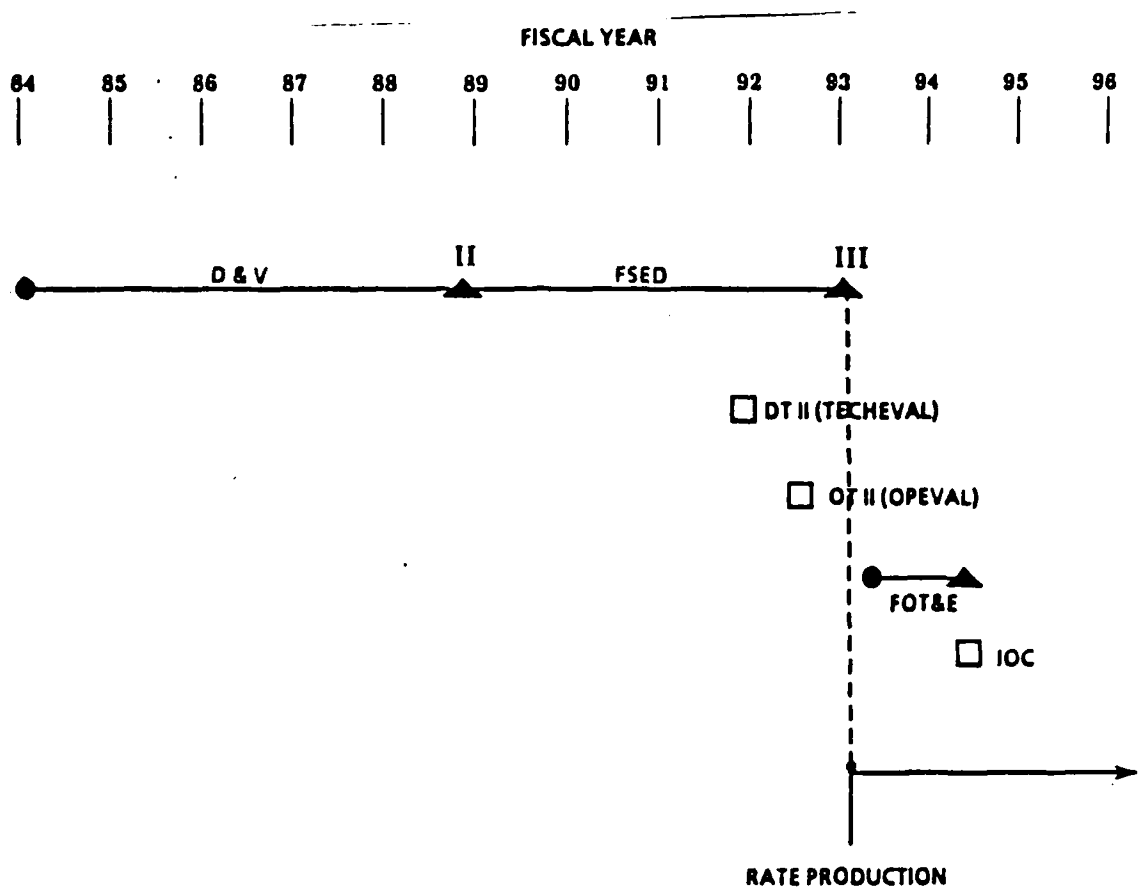

Figure 2

NOMOADS Program Structure

(NOMOADS OR, NCSC, Panama City, Florida)

The first major component is the torso. The NOMOADS torso is a pressure hull consisting of carbon fiber reinforced plastic and is the framework to which all other major components are attached.

The second major component consists of the arms. These are flexible in nature and can be easily moved about by the diver. The diver can pull his arms out of the NOMOADS arms and bring them inside the torso during a dive to adjust the life support equipment or the oral-nasal mask.

The legs comprise the third major component. They have flexible joints which allow the diver to walk about on the ocean floor. Attached to the legs are the boots which provide protection for the diver's feet.

Major component number four is the dome assembly. This consists of an outer protective dome and an inner pressure dome which seals against the torso to create an atmospheric environment for the diver, eliminating the need for any decompression. The dome also provides extensive visibility.

The fifth major component consists of the manipulators. These are connected to the arms and serve as specialized hands for the diver. The manipulators can open and close in order to grasp objects and perform various underwater tasks.

The sixth major component is the life support system. This includes one primary and one backup source of life support. Two oxygen cylinders are attached to the back of the torso and provide oxygen to the diver inside the suit.

Cannisters mounted inside the torso remove carbon dioxide from the breathing system while the oxygen is recycled in a closed circuit fashion. The oxygen supply is sufficent to provide life support for a maximum of forty hours.

Major component number seven is the communication system. This provides primary hardwire communications and secondary or backup through-water communications. During normal operations, the diver and topside support personnel are in constant communication with each other.

Major component number eight is the emergency system. This is comprised of a strobe for quick visual location, a pinger for sound location, ballast releases for emergency ascent, and a cable jettison for detachment of the umbilical.

The intensifier is the ninth major component. This device is mounted on the back of the torso and provides pressurized oil for joint lubrication.

Maintenance to be performed on these components at the organizational level is considered by NCSC to be outside the scope of diving certification. Those components requiring a higher level of maintenance will be considered to be within the scope of diving certification and this maintenance will be performed at the depot level.

C. OBJECTIVES

The main objective of this thesis is to examine the logistic support required to maintain NOMOADS throughout its life cycle. Subsidiary areas of research include parts support, maintenance, and training for NOMOADS operations. Appendix A provides a Draft Integrated Logistics Support Plan (ILSP) developed with the use of a computer program entitled Automated Logistics Planning (ALP). ALP is the current means by which the Naval Sea Systems Command is providing state of the art logistics planning for NOMOADS. ALP software allows quick and easy updating of the program database as changes occur. Appendix B provides a definition list of acronyms used in this thesis. Appendix C contains predive and postdive procedural checklists for NOMOADS.

The development of an Integrated Logistics Support Plan is critical to the program's success and will greatly assist current efforts at the Naval Coastal Systems Center in Panama City, Florida in meeting NOMOADS' current projected Initial Operational Capability (IOC) date of second quarter, FY94. Proper logistics planning must be conducted in the early stages of system acquisition in order to ensure maximum system effectiveness at minimum life cycle cost. The consideration of system reliability, maintainability, and availability factors early in the life cycle will help to prepare the way for optimal logistic support, and will

significantly increase the probability of program management success.

This thesis is in direct support of the Navy's NOMOADS program. The introduction of NOMOADS to the Navy's diving and salvage organization will result in improved diving support services for the fleet. The simplicity and increased depth capability of NOMOADS will allow Navy divers to complete a greater variety of underwater missions in less time and at less expense than is possible with current Navy diving systems.

D. METHODOLOGY

Thesis research was conducted at the Naval Coastal Systems Center (NCSC) in Panama City, Florida and at Oceaneering International in Santa Barbara, California. Information was gathered in on-site and telephone interviews with NCSC and Oceaneering personnel. Additional information was obtained from Slingsby Engineering, Ltd. of England, (the manufacturer of the system), the NOMOADS program office at the Naval Sea Systems Command (NAVSEA), the Naval Medical Research Institute in Bethesda, Maryland, the Naval Diving and Salvage Training Center (NDSTC) and the Navy Experimental Diving Unit (NEDU) in Panama City, Florida. An indoctrination dive using NOMOADS in Panama City provided valuable in-water experience.

II. BACKGROUND

A. ACQUISITION

The U. S. Navy became involved with JIM in 1978 when Dr. Arthur J. Bachrach began a biomedical assessment study of JIM-4 (developed by DHB Construction Ltd. of England) at the Naval Medical Research Institute in Bethesda, Maryland. Two JIM-4 diving systems were leased from Oceaneering International under Navy Contract Number N00024-75-C-2037 for this research. Completed in December, 1981, Dr. Bachrach's work helped to provide some of the momentum needed to begin the Navy's development and acquisition of NOMOADS. His research report defined the concept of a one-atmosphere diving system and provided good background information for NOMOADS program organization [Ref. 1].

Following Dr. Bachrach's work, Mr. Michael A. Troffer began engineering studies of NOMOADS at the Naval Coastal Systems Center in Panama City, Florida. Two carbon-fiber suits were purchased by the Navy for use at NCSC from Underwater and Marine Equipment Limited of England on a fixed price contract.

The current effort at the Naval Coastal Systems Center is to test a new carbon-fiber reinforced plastic (CFRP) torso for NOMOADS. NOMOADS must be Navy certified following Navy material certification procedures and criteria for

manned non-combatant submersibles. Testing is required for demonstration of structural integrity and material adequacy.

The civilian diving industry has traditionally used cast magnesium for the JIM torso, but the carbon-fiber torso promises to be lighter and stronger. The question is whether or not it can be safely used in the construction of a deep submergence system pressure hull.

The NOMOADS program is now in the Demonstration and Validation (D&V) phase. No milestone one exists for this acquisition program because it is designated as an Acquisition Category (ACAT) IVT. Much of the documentation for the NOMOADS program has been drafted at the Naval Coastal Systems Center (NCSC). The Test and Evaluation Master Plan (TEMP) provides fundamental guidance for ACAT III and ACAT IV programs [Ref. 4]. It contains information that is divided into several categories listed below.

Program Manager/Code: Joel Granet/NAVSEA PMS395

System Description: description of the system and its capabilities

Financial Summary: program funding by type and fiscal year

Critical Test and Evaluation Issues: description of test and evaluation criteria

Thresholds for Development Test and Evaluation (DT&E): min/max limitations

Operational Test and Evaluation (OT&E): submitted by Operational Test and Evaluation Force (OPTEVFOR)

Program Structure: Figure 2

DT&E Outline: procedural description

The OPNAV Program Coordinator, OPTEVFOR point of contact, and Operational Test Director should be listed in the finalized copy of the TEMP.

The NOMOADS Operational Requirement (OR) document was promulgated by OP-098 on 30 JUN 86 [Ref. 5]. It includes the information described below.

General description: system description and capabilities

Shortcomings of existing systems: description of depth and control limitations of present systems

Required capabilities: Table 1

Cost summary: Table 2

Platforms/quantities: types of platforms and number of systems

Integrated logistic support: maintenance description and location

Acquisition strategy: brief description of acquisition process

TABLE 1

CAPABILITIES REQUIRED

(NOMOADS OR, NCSC, PANAMA CITY, FLORIDA)

Operating depth	2,000 feet, maximum
Life support	20 hours nominal, 40 hours maximum
Current tolerance	1 knot, maximum
Manning level	6 maximum (diver, standby diver, surface support)
Refitting time between dives	2 hours, maximum
Air weight (unmanned)	1,000 lbs.
Water weight (manned, trimmed)	60 lbs.
Operator weight	150 lbs. min, 210 lbs. max
Operator height	70 in. minimum, 74 in. max
Water temperature	30 degrees Fahrenheit minimum, 65 degrees Fahrenheit maximum
Mission reliability	90% probability of completing a 20 hr mission
	Mean Time Between Failure of 200 hours
Frequency of use	60 operations/year/system
Maintainability	4 hours Mean Time To Repair for components outside the scope of diving certification
Inherent Availability	0.98

TABLE 2

COST SUMMARY

(NOMOADS OR, NCSC, Panama City, Florida)

(Constant FY88 $K)

	FY82-FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	Total
RDT&E	2140	1491	2212	1950	1250	1097	0	0	0	10140
Proc (1)	0	0	0	0	0	0	420	1260	840	2520
Op Exp (2)	0	0	0	0	0	0	0	5	0	5
Total	2140	1491	2212	1950	1250	1097	420	1265	840	12665

(1) 210K/system; Procurement Profile: FY93 (2 systems), FY94 (6 systems), FY95 (4 systems) for 12 systems total

(2) 2.5K/yr/system

Note: FY95 data above added by author

(Then Year $K)(3)

	FY82-FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	Total
RDT&E	2140	1491	2278	2067	1362	1229	0	0	10567
Proc	0	0	0	0	0	0	487	1504	1991
Op. Exp.	0	0	0	0	0	0	0	6	6
Total	2140	1491	2278	2067	1362	1229	487	1510	12564

(3) Assumes 3% inflation rate

Total Life Cycle Cost Limits (FY88 $K)

RDT&E	10140	
Proc	2520	(210K/system; Total 12 systems)
Op. Exp.	115	(5 years operation cost)
	12775	

Note: Projected end of system life cycle is fiscal year 2013

As stated above, the Operational Requirement describes the limitations of current Navy diving systems. The need exists for greater depth capability combined with simplified surface support requirements. This need can be met by NOMOADS. One advantage to having NOMOADS as a Navy diving system vice contracting out for similar diving services is quick response. In the event of an underwater emergency, a rescue can be accomplished quickly from Navy surface ship platforms. The requisitioning of commercial diving services for such a rescue could involve extensive time delays, resulting in an inadequate response to the emergency. Another advantage of having NOMOADS in the Navy's diving system inventory is that missions requiring information security can be conducted much more efficiently by using Navy personnel.

The cost summary displayed in Table 2 is based on a per system cost of $210,000. The cost of a carbon-fiber suit as of 23 NOV 87 is 305,447 pounds sterling [Ref. 6]. This price is valid until 30 SEP 88 and equates to $542,932.05 using the 20 NOV 87 exchange rate of $1.7775/pound sterling. The difference between the system cost stated in Table 2 and the current cost of one suit is due to the significantly different economic climate and monetary exchange rate, as well as the higher than expected inflation rate, in effect now. This can readily be expected when dealing with foreign companies. The procurement profile is 2,6,4 for 12 systems

total (two suits per system). This means that two systems will be procured in fiscal year 1993, six systems will be procured in fiscal year 1994, and four systems will be procured in fiscal year 1995 for a total procurement of 12 systems. The total estimated life cycle cost (in FY88 dollars) for 12 systems is $12,775,000. This includes RDT&E, procurement, and operational expenses for FY87-FY94. The projected end of the system's life cycle is fiscal year 2013, twenty years after initial procurement in FY93.

In the present acquisition strategy, two NOMOADS suits are being tested and evaluated. Hydrostatic testing of the torso has been performed by a civilian contractor in Panama City, Florida. Additional deep ocean simulation facilities are available at the Navy Experimental Diving Unit, located adjacent to the NCSC facility in Panama City. This testing will provide some of the data needed to write the certification standards for construction in accordance with directive NAVMAT P9290, System Certification Procedures for Deep Submergence Systems. The current goal is to have system certification standards written by FY90. TEMP revisions will be made as necessary to support Technical Evaluation (TECHEVAL) in FY91 and Operational Evaluation (OPEVAL) in FY92. Acquisition through a negotiated sole source, fixed price contract (necessary due to proprietary limb design) is planned for the first quarter of FY93. The second quarter of FY94 is the date set for Initial

Operational Capability (IOC), when the first certified system is delivered to the fleet for diving operations.

B. CONTRACTING

Government contracts involving NOMOADS have been written to include restrictions by the manufacturer precluding use or disclosure of technology concerning NOMOADS limb manufacture outside of the government. Reverse engineering of the limb design by the government or use of the hardware itself outside the government was also precluded. No technical data package (TDP) has been provided, so development of performance specifications and certification criteria is made much more difficult and time consuming. The contracting office at NCSC has recommended that if development of performance specifications does not succeed, negotiation between NCSC and the contractor may be necessary to provide for use of technical data for reprocurement purposes, as an alternative to sole source procurement. If sole source is deemed necessary, a Justification and Authorization (J&A) document will be required, lengthening the acquisition process.

Currently, there is only one company in the world which produces the JIM atmospheric diving system (ADS): Slingsby Engineering, Ltd. of England (formerly DHB Construction, Ltd.). Although there are other companies which specialize in underwater work, they do not possess the technology

required to manufacture NOMOADS. Research and development conducted to make another company competitive could significantly increase the system's acquisition cost.

The Armed Services Procurement Act (ASPA) of 1947 and the Federal Property and Administrative Service Act (FPASA) of 1949 are the principal statutes relating to government contracting [Ref. 7]. They require that competition be enforced by government agencies in procuring material and services. The government controls the contracting process by soliciting offers from sellers so that it can accept or reject the offers as it sees fit. Two major problems with ASPA and FPASA were: (1) negotiation was not considered a legitimate procedure for competitive procurement, and (2) non-competitive negotiation was not being sufficiently restricted.

The Competition In Contracting Act (CICA) of 1984 brought about changes to increase competition and to better control non-competitive sole-source procurement in government contracting. Congress recognized that although sole-source procurement is necessary in certain situations, it needs tight administration to ensure that competitive practices are used.

Sole-source procurement is authorized if it falls under one of seven exceptions to the standard competitive procedures. These seven exceptions are:

(1) Only one source exists for the materials or services required

(2) The need for materials/services is unusually urgent and failure to use a sole-source contract would harm the government

(3) A sole-source contract must be used to maintain essential U.S. industrial base/mobilization capability

(4) A sole-source contract is required to fulfill international agreement or treaty

(5) A specified source is required by law

(6) A sole-source contract is required to maintain national security

(7) The head of a government agency determines that a sole-source contract is in the public interest (Congress must be notified 30 days prior to contract award)

NOMOADS appears to qualify as a sole-source procurement under the first exception: only one source is available (Slingsby Engineering, Ltd.). In addition to meeting one of the seven exceptions to competition, NOMOADS must have a Justification and Authorization (J&A) statement approved by the procuring activity's Competition Advocate (for contracts over $100,000), or by the head of the procuring activity (for contracts over $1,000,000), or by the senior procurement executive of the agency (for contracts over $10,000,000). The most probable category for NOMOADS is that of several contracts over $1,000,000 in which the head of the procuring activity must approve the J&A statement. Once the J&A is approved, the agency publishes a notice of the proposed noncompetitive contract in the Commerce Business Daily for a period of 15 days.

There are two basic types of contracts, fixed-price type and cost type contracts. The fixed-price type is the one most preferred for government contracting because it encourages the contractor to minimize cost in order to maximize his profit. [Ref. 8] In a fixed-price contract, the contractor assumes the risk of guaranteeing performance for a fixed amount of money. The government's liability is limited to the amount of the fixed price.

The contract type specified for NOMOADS in the Operational Requirement is a fixed-priced contract [Ref. 5]. The fixed-price type contract is the best type for NOMOADS acquisition because of the fact that, except for the CFRP torso, NOMOADS can be purchased as a non-developmental item (NDI). NOMOADS is a modification of the JIM technology already in existence. The fixed-price type contract puts pressure on the contractor to deliver a product that will work. This is because the contractor is receiving a set amount of money for a system which must perform according to required specifications. If it doesn't, the contractor must pay to correct any problems. An advantage for the contractor (Slingsby Engineering, Ltd.) is that JIM technology has been thoroughly tested and proven since 1972.

Contracting involves two basic types of specifications: performance specifications and design specifications. A performance specification tells the contractor what the

product must do: how deep it must be able to dive, what water temperatures it must withstand, the amount of mobility required, etc. A design specification tells the contractor exactly how to build the system. With a proper design specification, any contractor with the manufacturing capability could build a suitable system.

We already know what JIM can do and has done. The problem with developing a design specification for NOMOADS is that Slingsby has proprietary rights to the design of the joints (arms & legs) and the government is prevented from conducting any reverse engineering or technology transfer. The joints used in the JIM system were developed to allow freedom of movement on the ocean bottom while maintaining watertight integrity at great depths. The technical data required to manufacture these specialized joints is proprietary information owned by Slingsby.

Warranties protect the government from defects that may become evident after product acceptance has occurred. Warranties commit the contractor to repair or replace defective products. The Uniform Commercial Code describes two major kinds of warranties: (1) express warranties, and (2) implied warranties. Express warranties include (a) hardware guaranties in which the contractor must correct defects appearing during a specified time period, (b) supply guaranties in which the contractor must replace or rework products with material or workmanship defects, and (c)

service guaranties in which the contractor provides services during a specific timeframe. Implied warranties imply that the product is merchantable and fit for the intended purpose.

III. LOGISTICS

A. RELIABILITY

Reliability is defined by Blanchard as

> ...the probability that a system or product will perform in a satisfactory manner for a given period of time when used under specified operating conditions. [Ref. 9:p.23]

Throughout the research conducted for this thesis, very little historical information was found concerning logistic support for JIM or NOMOADS. This was especially true in the areas of reliability and maintainability. The Royal Navy and the British Ministry of Defense have employed three JIM systems, but this has been done largely on an experimental basis providing limited data. The commercial diving industry has kept dive logs concerning the use of JIM, but the log entries examined are very brief and do not provide detailed descriptions of component or system lifetimes or the maintenance performed.

The lack of historical data required that engineering estimates be obtained in order to estimate reliability, maintainability, and availability of the system and its components. These engineering estimates were provided by the Naval Coastal Sy... Center located in Panama City, Florida and included m... time between failure (MTBF) and corrective maintenance time (Mct) [Ref. 10]. These estimates were based on projected operating time of 900

hours per suit per year. Table 3 shows how this corresponds to the Frequency of Use figure of 60 operations per year per system, stated in the Operational Requirement [Ref. 5].

TABLE 3

FREQUENCY OF USE

(SOURCE: NCSC, PANAMA CITY, FLORIDA)

60 Operations/Yr/System =

30 Operations/Yr/Suit x 2 Suits/System

Hrs/Dive		Dives/Day		Days/Operation		Operations/Yr/Suit	
6	x	1	x	5	x	30	=

900 Hrs/Yr/Suit

Calculations of system reliability, maintainability, and availability are made considering two suits operating in a series configuration. If one suit fails, the whole system is down temporarily because both suits must be in satisfactory operating condition in order to dive. One suit acts as a standby in case of an underwater emergency. The series configuration concept applies to NOMOADS beginning at the component level, as shown in Figure 3. If component A in suit #1 fails, the entire system is down until component A is repaired or replaced.

The calculations in this chapter use formulas contained in Blanchard's text on logistics engineering [Ref. 9].

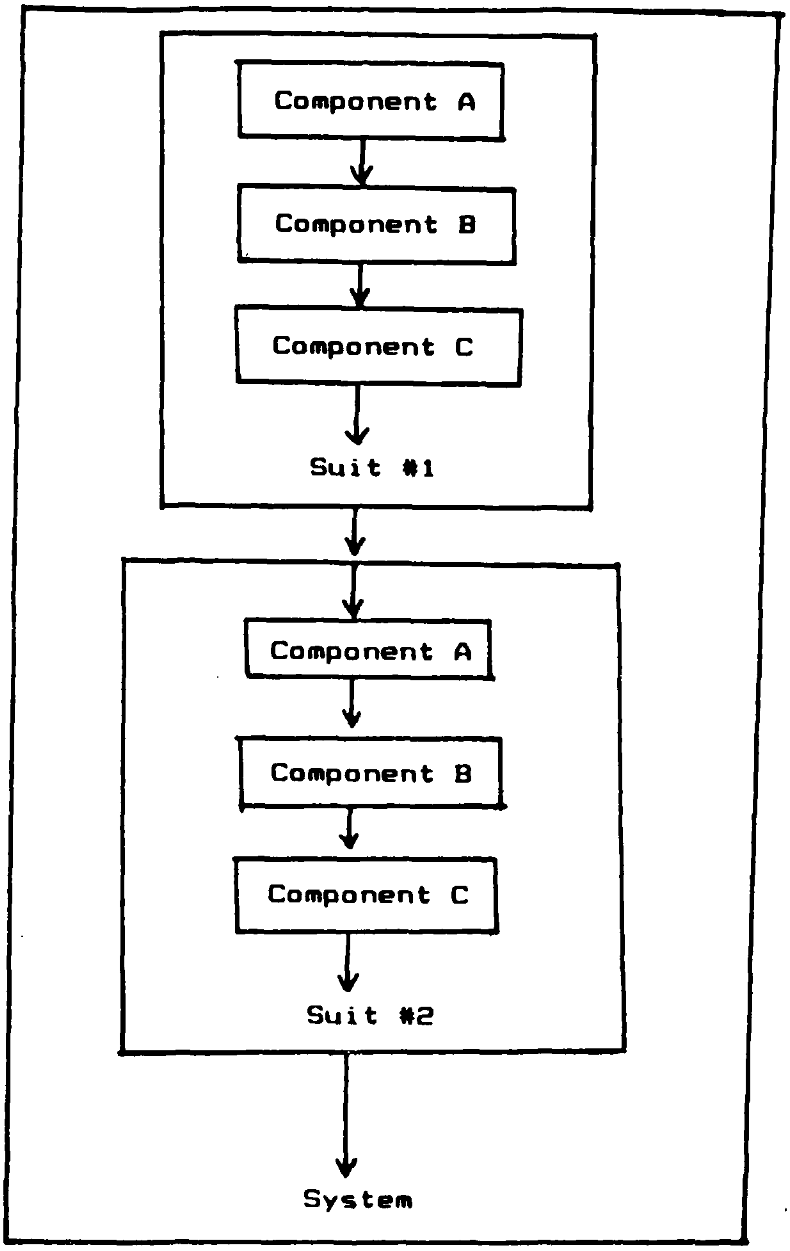

Figure 3

NOMOADS Series Configuration

The determination of system reliability was made by first determining the reliability of each of nine major subsystems and multiplying these reliabilities together to obtain overall reliability for one suit, and finally multiplying the reliabilities of two suits to get total system reliability. A time period of 20 hours was selected in order to make a comparison with the Operational Requirement [Ref. 5]. Table 4 provides the data and formulas used to calculate system reliability.

TABLE 4

SYSTEM RELIABILITY FOR A 20 HOUR MISSION

(SOURCE OF MTBF ESTIMATES: NCSC, PANAMA CITY, FLORIDA)

Component	MTBF (HRS)	Failure Rate	Relibaility
Torso	20000	.00005	.999
Arms	5000	.00020	.996
Legs	5000	.00020	.996
Dome Assembly	10000	.00010	.998
Manipulators	2000	.00050	.990
Life Support	2000	.00050	.990
Communication	2000	.00050	.990
Emergency	10000	.00010	.998
Intensifier	5000	.00020	.996

Failure Rate = 1/MTBF   Rsuit1 = [R1][R2]...[R9] = Rsuit2

$$\text{Reliability} = e^{-(\text{Failure Rate})(\text{Time})}$$

[Rsuit1][Rsuit2] = [.9541][.9541] = Rsystem = .9103 = 91.03%

Mean time between failure (MTBF) is the average time between conditions when a component or system fails to perform in a satisfactory manner in accordance with design specifications. System mean time between failure was determined by summing the failure rates of the nine major subsystems in one suit and doubling this sum to obtain a system failure rate. MTBF was calculated as the reciprocal of the system failure rate. Data and formulas for the calculation of system MTBF are contained in Table 5.

TABLE 5

SYSTEM MEAN TIME BETWEEN FAILURE

(SOURCE OF MTBF ESTIMATES: NCSC, PANAMA CITY, FLORIDA)

Component	MTBF (HRS)	Failure Rate
Torso	20000	.00005
Arms	5000	.00020
Legs	5000	.00020
Dome Assy.	10000	.00010
Manipulators	2000	.00050
Life Support	2000	.00050
Communication	2000	.00050
Emergency	10000	.00010
Intensifier	5000	.00020

Failure Rate (f) = 1/MTBF   f1 + f2 ... + f9 = f suit #1

f suit #1 = .00235   f suit #1 x 2 = f system = .0047

MTBF system = 1/f system = 1/.0047 = 212.766 HRS

The computations in Tables 4 and 5 implicitly assume that the major components fail independently of each other. For example, this means that a manipulator failure does not cause a communications failure, and an intensifier failure does not cause a life support failure. This is a safe assumption for most circumstances. Another common assumption used in these calculations is that the mean time between failure is exponentially distributed.

In general, the JIM system is reported to be highly reliable [Ref. 11]. Compared with saturation diving or complex underwater vehicles, JIM has proven to be simple and easy to maintain. Because it is an atmospheric diving system, there is very little that can go wrong with it compared to more complex systems.

B. MAINTAINABILITY

The following definition is provided by Blanchard for maintainability:

> ...an inherent design characteristic dealing with the ease, accuracy, safety, and economy in the performance of maintenance functions. [Ref. 9:p.32]

Maintainability measures the degree to which NOMOADS can be repaired quickly and easily at the job site so that underwater operations need not be interrupted for any great length of time.

One measure of maintainability is the mean corrective maintenance time ($\overline{M}ct$). This is the average time required

to

repair or restore the system to its full operational status.

Mean corrective maintenance time is equivalent to the mean time to repair (MTTR). [Ref. 9:p.34] Mean corrective maintenance time for NOMOADS was calculated for system components outside the scope of certification. This means only those items that can be repaired or replaced at the organizational level (ship or shore site). The data and formulas for the calculation of system $\bar{M}ct$ are shown in Table 6.

TABLE 6

SYSTEM MEAN CORRECTIVE MAINTENANCE TIME

(SOURCE OF Mct ESTIMATES: NCSC, PANAMA CITY, FLORIDA)

Component	Mct (HRS)	Failure Rate	Failure Rate x Mct
Torso	.75	.00005	.0000375
Arms	.50	.00020	.0001000
Legs	.50	.00020	.0001000
Dome Assembly	.50	.00010	.0000500
Manipulators	.50	.00050	.0002500
Life Support	.50	.00050	.0002500
Communication	1.00	.00050	.0005000
Emergency	1.00	.00010	.0001000
Intensifier	2.00	.00020	.0004000

$$\bar{M}ct = \frac{\text{Summation of [Failure Rate x Mct]}}{\text{Summation of Failure Rate}}$$

$$\bar{M}ct = \frac{.0017875}{.0023500} = .761 \text{ HRS} = 46 \text{ minutes} = \text{MTTR}$$

Slingsby Engineering Limited provided a detailed assessment of some of the major subassemblies in NOMOADS [Ref. 12]. Slingsby emphasized the importance of preventive maintenance in avoiding equipment difficulties, and reported that no one specific component or subassembly had shown a history of recurring maintenance problems.

Slingsby reported that the CFRP torso's life expectancy was more dependent on operational use of the torso than on its age. Due to the limited number of moving parts in the body subassembly, spare parts requirements for this subassembly have been limited.

The acrylic dome used in NOMOADS is considered to be one of the most easily damaged parts of the system. It can be damaged by physical scratches and by chemical action of the environment or solvents. Additionally, cracking of the dome is possible if it is dropped or hit with a heavy object while in use or in storage or both.

Maintaining the proper oil level within the joints of NOMOADS' arms and legs is important for system reliability. An intensifier located on the back of the torso is used to maintain proper oil level. The intensifier did not operate well in shallow water until it was modified by the U.S. Navy to provide a pre-load function at shallow depth.

During in-water operations conducted at the Naval Coastal Systems Center in Panama City, Florida, it was discovered that the manipulators on the arms required

frequent adjustment to ensure proper gripping ability. The manipulator assembly can be adjusted or replaced on-site in a short period of time to keep the system operating.

The life support system consists of closed circuit oxygen rebreathing apparatus. If breathing problems develop with a unit, there is a backup unit that a diver can switch to using flow control valves located inside the torso.

A common problem encountered during use of JIM and NOMOADS is fogging of the acrylic dome. This is caused by the extremely high level of humidity within the torso during a dive. The one method found to deal with this fogging problem is for the diver to carry paper towels with him (her) to periodically clear the inner surface of the dome. Use of chemical solutions to prevent fogging could have an adverse effect on the dome and is not recommended.

A diver requiring corrective lenses is much better off with contact lenses than glasses when diving with NOMOADS because the diver's glasses frequently fog, compounding the problem of dome fogging. The British Ministry of Defense reported using five pound bags of silica gel as a desiccant in the arms and legs of its JIM suits during storage to help reduce the amount of suit moisture [Ref. 13].

Details concerning preventive maintenance procedures for NOMOADS are contained in the Operation and Maintenance Manual. Table 7 shows scheduled maintenance periodicity for system components. [Ref. 14]

TABLE 7
SCHEDULED MAINTENANCE INDEX (PERIODICITY)
(OPERATION AND MAINTENANCE MANUAL)

INSPECTION (TEST) AND/OR CLEANING	PRE DIVE	POST DIVE	100 HRS	200 HRS	400 HRS	800 HRS	2400 HRS	ADD. REQ.
ADS SUBSYSTEM								
ADS Suit								
Arms	X	X						X
Legs	X	X						X
Torso-Vent Valve-Depth Gauge Penetrator	X	X						X
Dome Assembly	X	X	X					
Manipulators	X	X			X			X
Depth Gauge								X
Life Support								
O_2 Bottles	X	X				X		X
Combined Reducer-Shut Off Valve	X					X		X
O_2 Flow Controller	X				X			
Changeover Valve	X							
Inhale and Exhale Canisters	X	X						
Gauges and Instrumentation	X					X		X
Oral-Nasal Mask	X	X						
Communication								
Hardwire	X	X						X
Through-Water	X	X						X
Emergency								
Strobe-Flasher	X	X						
Pinger	X	X		X				X
Ballast Releases	X							
Cable Jettison	X							
Electrical and Lighting								
Battery Pack	X	X			X			X
Light	X							
Hydraulic Intensifier Unit	X	X				X		X
ADS HANDLING SUBSYSTEM								
Winch								
Tether-Communication Cable		X						
Motor	X		X		X			X
Drum(s)	X			X	X			X
Slip Rings								X
Brake	X							X

C. AVAILABILITY

Availability can be considered a measure of system readiness. One type of availability is inherent availability (Ai).

> Inherent availability is the probability that a system or equipment, when used under stated conditions in an ideal support environment (i.e., readily available tools, spares, maintenance personnel, etc.), will operate satisfactorily at any point in time as required. [Ref. 9:p.64]

Inherent availability for NOMOADS was calculated using system mean time between failure and system mean corrective maintenance time. The formula and calculations are shown below.

$$Ai = MTBF/[MTBF + Mct] = 212.766/[212.766 + .761] = .9964 = 99.64\%$$

D. TRADEOFFS

An important part of any logistics support plan is the consideration of many different tradeoffs among various factors. These factors include such things as maintenance time, maintenance cost, reliability, maintainability, availability, and training requirements. Tradeoffs must be identified and evaluated in order to produce the most effective and efficient logistic support possible throughout the system's life cycle. This section of the thesis describes some of the tradeoffs found in NOMOADS.

Research conducted by Moore and Fabrycky revealed nine subproblems of Repairable Equipment and Logistic (REAL)

systems. [Ref. 15] These subproblems help to identify tradeoffs in NOMOADS logistic support.

The first subproblem is the Mechanic Training Problem (MTP). The question of who will maintain NOMOADS equipment and where these personnel will be trained brings up the first tradeoff consideration: how does the cost of training Navy personnel to perform NOMOADS maintenance compare with the cost of having maintenance performed by an outside source? Another consideration is the level of maintenance quality which will be attained by Navy vs contractor personnel. Oceaneering International in Santa Barbara, California estimated that approximately 90 to 95 percent of all maintenance actions could be performed onboard a support vessel. [Ref. 11] This indicates that it may be possible to have Navy divers perform the majority of required maintenance at the organizational level (onboard ship).

The second subproblem is the Optimal Level of Repair/Level of Repair Analysis Problem (OLP). This subproblem identifies a tradeoff between the benefits of rapid shipboard repair and the negative effects of an increased inventory of diving support equipment that would have to be carried onboard. In Appendix A, it is recommended that there be only two levels of maintenance support, namely organizational and depot. Based on the system mean corrective maintenance time of 40 minutes and the high percentage of organizational level maintenance, an

intermediate maintenance level does not appear to be necessary for NOMOADS. Any repairs that could not be performed locally could be sent directly to the proposed depot level maintenance facility in San Diego, California.

The Naval Coastal Systems Center predicts that depot level maintenance will be performed on each system every two years. This depot maintenance will include those maintenance requirements that are within the scope of certification (beyond the capability of the organizational level). The omission of intermediate level maintenance could save significantly on life cycle cost by reducing facility and transportation costs.

The third subproblem is the Machine Design Problem (MDP). This identifies the tradeoff between development of carbon fiber reinforced plastic (CFRP) and the use of magnesium alloy in the NOMOADS torso. Another tradeoff exists between the amount of engineering design and the amount of maintenance required to keep the system operational. At present the forecasted reliability is quite high and the corrective maintenance time is so low that only very inexpensive engineering design efforts may be worthwhile to increase reliability and decrease Mct.

Research findings from Oceaneering International and the British Ministry of Defense (MOD) reveal that the carbon fiber reinforced plastic promises to be a much superior material for use in the torso than is magnesium alloy. The

magnesium torsos have had frequent corrosion-related problems requiring excessive maintenance, resulting in increased maintenance costs and reduced useful life of the system. The carbon fiber torsos promise to require much less maintenance.

A carbon fiber JIM system with mid-water capability (JIM 22) has been produced by Slingsby Engineering Limited for the British Ministry of Defense. [Ref. 16] This indicates that a CFRP NOMOADS can now be procured as a basically non-developmental item, with consideration given to testing and evaluation of the system to ensure compliance with Navy system certification procedures. The procurement of a CFRP vice magnesium alloy NOMOADS will provide a diving system with greater maintainability and availability, resulting in increased system effectiveness.

Subproblem number four is entitled the Maintenance Configuration Problem (MCP). This involves the question of how many maintenance levels to use for NOMOADS, and what tools/materials will be required at each maintenance level. The tradeoff in this case is between the lower cost of fewer maintenance levels or activities and the level of service which could be achieved with a higher number of maintenance levels. As stated in the discussion of subproblem number two, it is recommended that only two maintenance levels, organizational and depot, be used. Given the fact that any particular ship will probably have only one NOMOADS (i.e.

two suits), organizational level maintenance will never need more than two service channels. In fact, one service channel should do nicely since mean corrective maintenance time and the failure rate are so low. As the Navy intends to own only 24 suits, a single service channel at the depot level is also likely to be sufficient unless actual depot level failures occur much more frequently than forecast.

The tools required for the majority of NOMOADS maintenance could easily be carried onboard a ship. The less frequently required but more complex maintenance actions could be performed at one depot level facility. The limited number of systems (twelve) to be procured (two suits per system, or 24 suits total) would require only one depot level activity to properly maintain all systems. The centralization of depot level maintenance combined with the decentralization of organizational level maintenance should result in the most cost effective maintenance system.

The fifth subproblem is the Spare Machine Problem (SMP). This brings up the cost/benefit tradeoff question of how many NOMOADS systems should be purchased. The proposed number of twelve systems appears to be reasonable considering the global mission of the U.S. Navy. Twelve systems would allow NOMOADS deployment from both east and west coast ships, as well as from flyaway units at shore sites. It is proposed that eight systems be deployed on Navy ships (four for the Atlantic and four for the Pacific),

and three systems be deployed from mobile dive teams or other shore activities. The twelfth system could be used for training at the Naval Diving and Salvage Training Center and the Naval Coastal Systems Center in Panama City, Florida. It is emphasized again that a NOMOADS system will consist of two suits and their associated handling equipment.

Subproblem number six concerns the Preventive Maintenance Policy (PMP). Slingsby Engineering Limited, the manufacturer of JIM systems, has stated that the importance of the proper and timely accomplishment of preventive maintenance for these diving systems cannot be overemphasized [Ref. 12]. The tradeoff in this case is easy: do the maintenance or risk the cost and safety consequences of not doing the maintenance. It is suggested that the preventive maintenance procedures contained in the NOMOADS Operation and Maintenance Manual be incorporated into the standard Navy PMS after development procedures ensure that Navy requirements for system certification will be met.

The seventh subproblem deals with the Replacement Policy Problem (RPP). When should a system or part of a system be taken out of service permanently and replaced? One of the purposes of the Demonstration and Validation phase of NOMOADS acquisition is to demonstrate that carbon fiber is suitable for use in NOMOADS torsos and that carbon fiber

will meet all depth and pressure strength requirements for system certification. Provided that the development of carbon fiber technology is successful, it is expected that NOMOADS systems should be capable of a lifetime of twenty years or longer, given that proper maintenance is performed when required. Except in the event of catastrophic failure of a NOMOADS subassembly, the determination of when a suit or component will be retired from use should be made at the depot level. This determination will represent a tradeoff between equipment reliability and cost. The most important consideration in this tradeoff decision must be diver safety. Recommended depot level procedures were provided by the Naval Coastal Systems Center and are listed in Table 8.

Subproblem number eight is the Inspection and Testing Policy (ITP). Manufacturer recommendations will play an important role in determining the frequency and extent of NOMOADS test and inspection procedures. The tradeoff is again a cost/benefit consideration. Frequent testing and inspection may increase costs, but these procedures will increase safety and reliability. Test and inspection procedures are described in the Operation and Maintenance Manual [Ref. 14]. These test and inspection procedures include pre-dive and post-dive maintenance requirements as well as routine preventive maintenance actions.

The ninth and final subproblem described by Moore and Fabrycky is the Operator Training Problem (OTP). This

TABLE 8
RECOMMENDED DEPOT LEVEL PROCEDURES
(SOURCE: NCSC, PANAMA CITY, FLORIDA)

Component/Subassembly	Maintenance
Arm	Complete disassembly, cleaning, replacement of component parts, and reassembly
Leg	Same as arm
Torso vent valve	Repair/replace vent valve assy.
Dome Assembly	Dome evaluation, and if necessary, return to manufacturer for repair/replacement
Manipulators	Complete disassembly, replacement of component parts, and reassembly
Depth gauge	Calibration
O2 bottles	Visual inspection, hydrostatic testing, and cylinder tumbling
Combined reducer-shutoff valve	Complete disassembly, replacement of component parts, and reassembly
Oxygen flow controller	Same as reducer-shutoff valve
Changeover valve	Same as reducer-shutoff valve
Gauges and instrumentation	Calibration
Hardwire Comms	Circuit tests and repair/replacement as necessary
Through-water Comms	Same as hardwire comms
Ballast Releases	Replace penetrator seal
Cable Jettison	Same as ballast releases
Battery Pack	Discharge test and repair/replacement as necessary
Intensifier	Disassemble, replace component parts, and reassemble

subproblem suggests a tradeoff between the diver's skill level with NOMOADS and the cost of training.

Diving with NOMOADS is a unique experience. It is unlike any other type of Navy diving. The weight range of NOMOADS divers is from 150 to 210 pounds. In-water experience has shown that divers at the higher end of the weight scale have a significant advantage in the initial phase of NOMOADS training. A diver's weight must be shifted in the suit to perform various tasks, and a heavier diver is more successful in initial adaptation. After gaining several hours of in-water practice, however, the lighter weight diver can perform equally as well.

It is suggested that NOMOADS training consist of at least 30 hours of in-water time per diver, and that the diver meet certain task requirements prior to being qualified. These task requirements should include emergency procedures, manipulator dexterity drills, and suit maneuverability drills. This will help to ensure that a diver will be able to perform safely and successfully in the open water environment. The 30 hour requirement could be reduced to a five hour requirement if the purpose was to allow a specialist such as an oceanographer to use NOMOADS as an observation platform rather than to conduct complex underwater tasks. The five hour requirement would concentrate on system familiarization and emergency procedures. In this case, the standby diver should be fully

qualified under the 30 hour requirement to ensure adequate assistance in the event of an emergency.

The nine subproblems discussed above have revealed some of the more important tradeoffs to be considered in NOMOADS acquisition. It should be remembered that these tradeoffs almost always require cost/benefit decisions. If these decisions are made with consideration given to diver safety and life cycle cost, the probability of optimizing system effectiveness will be enhanced.

E. SPARE PARTS AND LIFE CYCLE COST

Traditionally, logistic support planning has consisted of loadout lists for JIM that were compiled by individuals experienced in the use of JIM systems. These lists were tailored to specific job assignments and provided an estimate of the number of spares required for the particular job based on past work experience. In addition to routine maintenance, any necessary repairs were conducted on an as needed basis, and parts not carried in inventory were ordered or manufactured when needed. [Ref. 11]

Slingsby Engineering Limited provided information concerning recommended spares for each NOMOADS system [Ref. 12]. For the acrylic dome subassembly, it was recommended that a spare protective dome be carried for each suit, and a spare complete dome subassembly for each system (pair of suits). Additionally recommended system spares included:

(1) 2 manipulator subassemblies

(2) 1 complete leg subassembly (leg and boot)

(3) 2 reducer valves and gauges

(4) 2 flow controllers (one port and one starboard)

(5) 2 oxygen concentration cells

(6) 8 batteries for battery packs

(7) 2 oral nasal mask/microphone assemblies

(8) 1 throughwater/hardwire communications panel

(9) 1 through-water transducer

(10) 1 transducer plug, socket, and cable

(11) 1 battery plug, socket, and cable

(12) 1 pinger

(13) 1 flasher

(14) hull pressure relief valve

Estimates of component lifetimes were unavailable from Slingsby. However, prices of the following subassemblies were provided:

(1) Arm including manipulators	16,302 pounds sterling
(2) Leg including boot	15,287 pounds sterling
(3) Complete dome assembly	10,060 pounds sterling

Conversion to American dollars at the exchange rate in effect on 20 NOV 87 provides the following cost estimates for Slingsby recommended spares for one NOMOADS system (includes only those subassemblies listed):

(1) Arm including manipulators	\$ 28,976.81
(2) Leg including boot	\$ 27,172.65
(3) Complete dome assembly	\$ 17,881.65
Total =	\$ 74,031.11

(Conversion Factor: \$1.7775/pound sterling)

This total of \$74,031.11 amounts to 35.25% of one system's acquisition cost at \$210,000 per system.

Life cycle cost refers to the total cost of developing, procuring, operating, maintaining, and retiring a complete system. The costs involved in a system's use can span many years and thus add up to much more than the procurement cost alone. An examination of all costs involved is required to provide an accurate representation of what is termed life cycle cost.

Preparation of an accurate estimate of life cycle cost is critical to sound logistics planning. A revision of the Automated Logistics Planning software used in the preparation of Appendix A is being developed for NAVSEA by Analysis and Technology, Inc. to include a section on life cycle cost. This revision will greatly facilitate the preparation of a comprehensive life cycle cost estimate for NOMOADS.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The researching of integrated logistic support for NOMOADS has shown that to maximize effectiveness and efficiency, planning for logistics support must begin in the Concept Evolution phase of the acquisition process. Funding for logistic support of an operational system must begin during this initial phase.

Table 9 compares the system capability requirements listed in the Operational Requirement (Reference 5) with the system capability calculations made based on the engineering estimates provided by the Naval Coastal Systems Center.

TABLE 9

CAPABILITY REQUIREMENTS VS CAPABILITY ESTIMATES

Capability	Required	Estimated
Reliability	.9000/20 HRS	.9103/20 HRS
MTBF	200 HRS	212.766 HRS
MTTR	4 HRS	46 Minutes
Ai	.98	.9964

Table 9 shows that NOMOADS capability estimates exceed NOMOADS capability requirements. This indicates that based on engineering estimates, NOMOADS will be able to perform as specified in the Operational Requirement.

The fact that NOMOADS consists of a series configuration of component parts and subassemblies has a major effect on system reliability. Each component, subassembly, and suit must function properly in order for the entire system to perform in a satisfactory manner. Thus, any errors in the major component failure rate estimates could be very significant. This increases the importance of accurate and complete performance of regular maintenance procedures. These maintenance procedures are well documented in the Operation and Maintenance Manual for NOMOADS [Ref. 14]. One conclusion made from this research is that NOMOADS is a highly maintainable system.

The calculated mean time to repair is significantly less than the required time. This supports the conclusions that much of the system's maintenance can be performed at the organizational level and that an intermediate maintenance level may not be necessary. Table 8 shows the type of maintenance that will typically be required for each system every two years. The Naval Coastal Systems Center has recommended that this maintenance be performed at the depot level. Thus, there appear to be only two maintenance levels required for NOMOADS: organizational and depot.

The estimate of inherent availability is also significantly higher than the system requirement. This is due in part to the rapidity with which system failures can be corrected on station at the organizational level. This is one of the many advantages of atmospheric diving systems compared with other diving systems which use complex life support equipment.

Spare parts for NOMOADS which will be carried in inventory at the organizational level will consist of those parts which can be repaired or replaced on-site. The simplicity of the system contributes to its reliability and reduces the number of spare parts which must be carried. Additional spare parts inventory will be carried at the depot level maintenance activity in order to conduct the more complex repairs that will not be accomplished at the organizational level. Due to the high MTBF for most subsystems, large numbers of spare parts are not expected to be required.

The development of carbon fiber reinforced plastic for use in the NOMOADS torso promises to be a successful modification of the JIM system. The use of CFRP is expected to significantly reduce maintenance time and life cycle cost as well as improve system reliability.

The implementation of computerized logistics through Automated Logistics Planning will be a major benefit to the NOMOADS program. It will identify those program events

which must take place to ensure proper logistic support for NOMOADS throughout the system's life cycle.

The introduction of NOMOADS to the U.S. Navy diving equipment inventory will provide an excellent alternative to present saturation diving techniques, and will also greatly extend the operating depth capability without requiring time consuming, dangerous, and expensive decompression. While saturation diving will continue to have its own specific areas of mission application, NOMOADS will reveal new horizons by permitting a more expansive role for Navy divers.

In summary, the Navy One-Man One-Atmosphere Diving System has the capability of providing a highly reliable and maintainable diving system to improve fleet support. The use of an Integrated Logistic Support Plan for NOMOADS will help to ensure that system effectiveness is maximized throughout the system's life cycle.

B. RECOMMENDATIONS

As a result of the research findings made through this thesis study, several recommendations concerning logistic support for NOMOADS are provided.

First, it is recommended that a finalized Integrated Logistic Support Plan be developed, approved, and implemented as soon as possible. This can best be

accomplished through the use of the Automated Logistics Planning software described in Appendix A.

Data should be recorded for all U.S. Navy activity in the development and operational use of NOMOADS. This should include comprehensive maintenance records and spare parts utilization data for all NOMOADS systems. This will provide a comprehensive historical database which will greatly facilitate future logistics planning for system modifications such as the mid-water (flying) capability which exists in JIM 22, owned by the British.

It is recommended that the Operation and Maintenance Manual for NOMOADS (Reference 11) be used in the development of Navy Preventive Maintenance System (PMS) procedures for the system. This will ensure continuity with current practice and minimize maintenance problems in the future.

Two levels of maintenance should be assigned for NOMOADS. These levels are organizational and depot. One depot level maintenance facility should be established in San Diego, California to perform biennial depot maintenance on all NOMOADS equipment.

Training for operation and maintenance of NOMOADS at the organizational level should be conducted at the Naval Diving and Salvage Training Center in Panama City, Florida. This training should require a minimum of 30 hours of in-water time as part of the qualification process for each NOMOADS diver. Training for depot level maintenance personnel

should be conducted at the Naval Coastal Systems Center in Panama City, Florida.

APPENDIX A

NOMOADS INTEGRATED LOGISTICS SUPPORT PLAN (DRAFT)

This Integrated Logistics Support Plan was prepared using Automated Logistics Planning (ALP) software. This software was developed for the Naval Sea Systems Command by Analysis and Technology, Inc. It consists of six floppy disks which can be used with an IBM or IBM compatible computer. After entering basic program data into the database, ALP generates the ILSP including milestones to be accomplished during the system's life cycle. This data can be modified quickly and easily as events occur and changes take place in the system's acquisition. ALP is currently being revised to include a section on life cycle cost.

NAVSEA ILSP NO: Draft
Program Office
Code: PMS395
User ID:10089

INTEGRATED LOGISTIC SUPPORT PLAN

FOR THE MANAGEMENT OF

Navy One-Man One-Atmosphere Diving System
TBD

ACQUISITION CATEGORY (ACAT) IVT

D & V

APPROVAL SIGNATURES AND DATE

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ILS Manager

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Program Manager J. Granet PMS395

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DEP CDR/Designated Proj Mgr

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INTEGRATED LOGISTICS SUPPORT (ILS) PLAN

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RECORD OF CHANGES

Change No.	Date	Title or Brief Description	Entered By

PROGRAM DOCUMENTS

DOCUMENT/TITLE	NUMBER	DATE
DECISION COORDINATING PAPER (DCP):		
INTEGRATED PROGRAM SUMMARY (IPS):		
JUSTIFICATION FOR MAJ SYS NEW STARTS (JMS&S):		
NAVY DECISION COORDINATING PAPER (NDCP):		
NAVY TRAINING PLAN (NTP):	TBD	TBD
OPERATIONAL REQUIREMENT (OR):	107-02-87	6/30/86
SYSTEM CONCEPT PAPER (CSP):		
TEST AND EVALUATION MASTER PLAN (TEMP):	Draft	4/01/87
TECH MANUAL CONTRACT REQMNTS (TMCR):		
PROGRAM CONTRACT:		
PROGRAM CONTRACT:		
PROGRAM CONTRACT:		
TECH MANUAL: NOMOADS O & M Manual		
TECH MANUAL:		
TECH MANUAL:		
OTHER:		
OTHER:		
OTHER:		

SECTION 1.0

1.0 BACKGROUND AND SYSTEM CHARACTERISTICS

This section contains a brief background statement identifying reasons for program initiation, new or upgraded capabilities provided by the proposed acquisition, improvements in operation, mission effectiveness, and a brief description of the system/equipment.A pictorial diagram (figure 1-1) and a list of equipment to be installed and removed (sections 1.6 and 1.7) is also provided.

1.1 Reason for Program Initiation

Current deep diving operations to a depth of 850 feet of salt water (FSW) require complex saturation diving techniques and systems which are difficult and costly to maintain. Decompression is required and greatly increases the time required to achieve results.

1.2 Purpose of System

The purpose of NOMOADS is to perform no-decompression diving operations to a maximum depth of 2000 FSW. NOMOADS mission areas will include underwater search, location, salvage, rescue, photography, and explosive ordnance disposal.

1.3 Principle of Operation

A NOMOADS system consists of one diving suit, one standby diving suit, and associated handling equipment. These systems will be deployed on ARS and ASR type vessels and at shore sites with fly-away capability. NOMOADS can descend quickly to a depth of 2000 FSW, perform its mission, and return to the surface without requiring decompression.

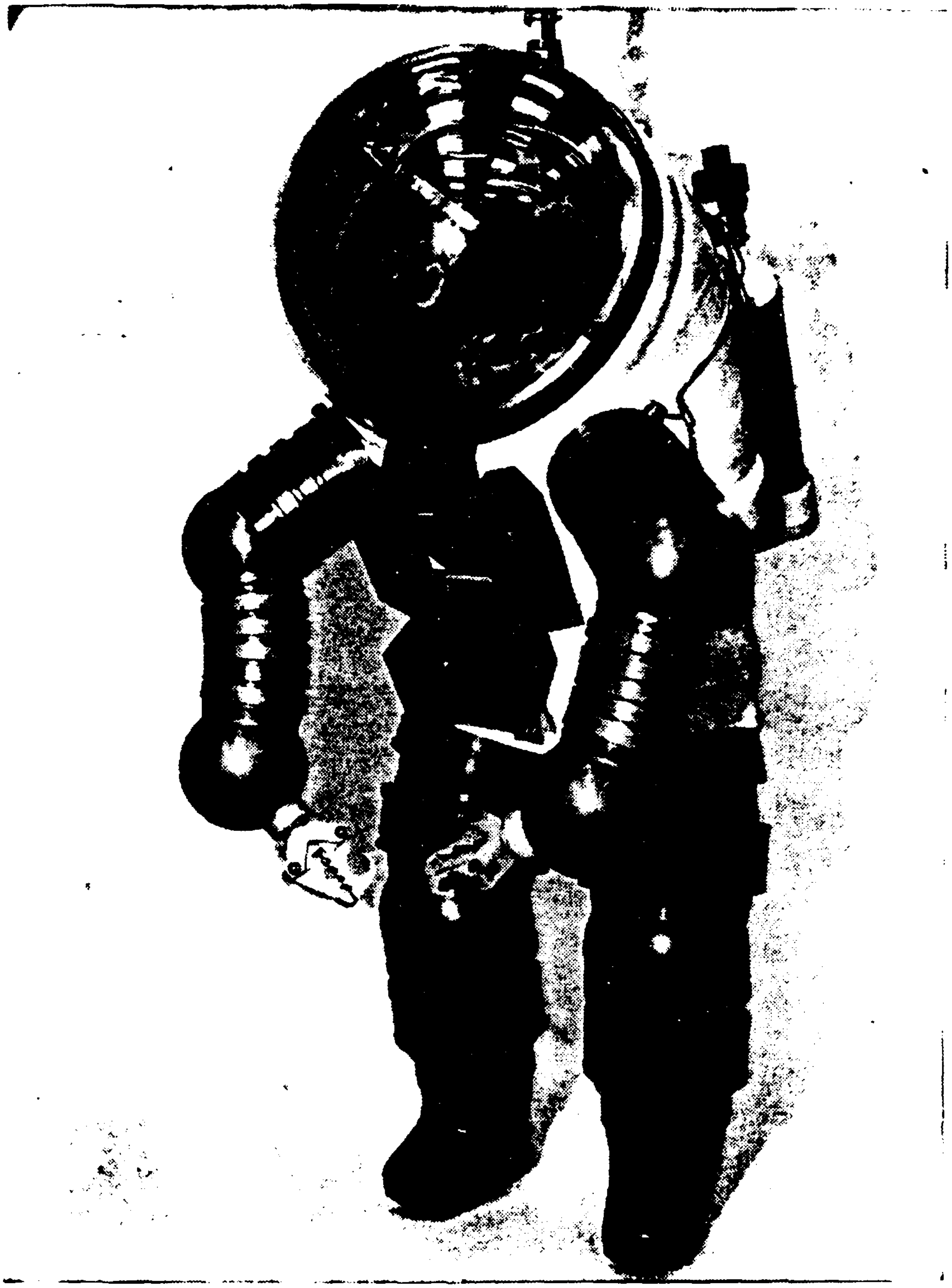

Figure 1-1
NAVY O'.E-MAN ONE-ATMOSPHERE DIVING SYSTEM (NOMOADS)
(Courtesy Slingsby Engineering Limited)

1.4 Improvements

The system will provide improvements in the areas indicated below.

PERFORMANCE: Y: LIFE CYCLE COST: Y: VULNERABILITY: Y:
RELIABILITY: Y: SUPPORTABILITY : Y: OPERABILITY : Y:

The following new/upgraded capabilities will be provided:

Carbon fiber reinforced plastic is being tested for use in the NOMOADS torso. This should significantly improve reliability and maintainability as well as reduce life cycle cost. Additionally, "flying" or midwater capability is available as a system upgrade.

1.5 Summary of System Physical Characteristics

OVERALL SIZE: AREA		(SQ FT)	: 20
	VOLUME	(CU FT)	: 15
	MAX HEIGHT	(FT/IN)	: 6 FT, 8 IN
	MAX WIDTH	(FT/IN)	: 3 FT, 8 IN
	MAX LENGTH	(FT/IN)	: 4 FT, 0 IN

POWER REQUIREMENTS (KW) : 24 Volt

OVERALL WEIGHT (LBS) :1000 lbs

1.6 Subsystems/Equipment/Components to be Installed

Torso
Arms
Legs
Intensifier
Manipulators
Dome
Life Support
Communications
Emergency

1.7 Subsystems/Equipment/Components to be Removed

None

SECTION 2.C

2.0 ILS ELEMENT MANAGEMENT AND PARAMETERS

This section briefly describes the basic concepts upon which logistics support will be based. Significant factors for each ILS element are outlined below to identify only unique characteristics; normal requirements described in the milestones and the milestone descriptions in Appendix A of NAVSEANOTICE 4105 of 28 June 1985 are not repeated.

2.1 Maintenance Planning

2.1.1 Maintenance Concept. The maintenance concept for the system and the maintenance to be performed at each level; i.e., organizational, intermediate, and depot are summarized in the table below:

Table 2-1

MAINTENANCE ACTION	ORG(%)	INT(%)	DEPOT(%)
PREVENTIVE MAINTENANCE:	95	0	5
DIAGNOSTICS/GEN. PURPOSE TEST EQUIP:	10	0	90
LOWEST UNIT REPLACEMENT:	90	0	10
ADJUSTMENTS:	95	0	5
ALIGNMENTS:	95	0	5
UNIT REPLACEMENT:	5	0	95
OPERATIONAL TEST:	10	0	90
OVERHAUL REFURBISH:	10	0	90

2.1.2 Availability. The system availability requirements and component parameters include:

OPERATIONAL AVAILABILITY (Ao)	(PERCENT):	98
RELIABILITY (MTBF)	(HOURS):	200
MAINTAINABILITY (MTTR)	(HOURS):	4
MEAN LOGISTICS DELAY TIME (MLDT)	(HOURS):	None specified
MEAN DOWN TIME (MDT)	(HOURS):	None specified
SYSTEM LIFE	(YEARS):	20
MISSION DURATION	(HOURS):	6

2.1.3 Maintenance Analysis.

Level of Repair Analysis (LORA) to be conducted per MIL-STD-1390B.
The LORA model to be used is :
Level of Repair Analysis was based on NCSC engineering estimates. No explicit LORA model was used.

Logistic Support Analysis (LSA) to be conducted per MIL-STD-1388-2A.
The Level of LSA to be used is : the system level.

2.2 Manpower, Personnel, Training, and Training Support

2.2.1 Training Plans. Navy Training Plan under preparation.

TRAINING OBJECTIVES DEVELOPED	: N
TRAINING CURRICULUM DEVELOPED	: N
FACTORY TRAINING OF INITIAL OPERATORS	: N
FACTORY TRAINING OF INSTRUCTORS	: N
NAVY COURSES AND PIPELINE IDENTIFIED	: N

Organizational level operations and maintenance training will be conducted at NDSTC, Panama City, Florida. Depot level maintenance training will be conducted at NCSC, Panama City, Florida.

2.2.2 Training Equipment/Devices

Table 2-2

TRAINING EQUIPMENT/DEVICES	LOCATION
NOMOADS	NDSTC and NCSC, Panama City,FL
NOMOADS Step Platform	NDSTC and NCSC, Panama City,FL

2.2.3 Manpower, Personnel and Training Constraints

Manpower Constraints:

NOMOADS manpower requirements will be filled from the diving community.

Personnel Constraints:

Minimum Height = 68 inches, Maximum Height = 74 inches
Minimum Weight = 150 lbs, Maximum Weight = 210 lbs

Training Constraints:

Training will consist of a minimum of 30 hours of in-water operation per individual to meet minimum NOMOADS diver qualification standards.

2.3 Supply Support

The following paragraphs provide planning information for supply support.

2.3.1 Supply Support Concept

Formal NAVY provisioning and supply support through the Navy supply system is planned. Y

Ships Parts Control Center (SPCC) will be the Program Support Inventory Control Point. Y

The Life Cycle Support Manager is: Not designated at this time

2.3.2 Interim Supply Support

Interim supply support required. Y

The period of interim supply support is from 1187 (MMYY) to 1095.

The interim supply support activity is: Slingsby Engineering, Ltd.
Kirkbymoorside, York, England

2.4 Support Equipment

2.4.1 Unique Support Equipment

The following is a list of unique support and test equipment and quantity required at each maintenance level.

Table 2-3

NOMENCLATURE	DESCRIPTION	MAINTENANCE LEVEL ORG	INT	DEPOT
Handling Equip	NOMOADS Support Stand	24	0	6
Joint Ring Tool	Special Maintenance Tool	12	0	3
Spanner Wrench	Special Maintenance Tool	12	0	3

2.4.2 Miniature/Microminiature Electronic Repairs

Miniature/microminiature (2M) Electronic Repair to be employed per NAVSEAINST 4700.19A and NAVSEAINST 4790.17. Y

Electronic repair capability will be required to maintain communications system.

2.5 Technical Data

There will be variation from existing governing instruction regarding technical data. The following variations are described below:

TECH MANUALS: currently unknown
TM CONTRACT RFQ: currently unknown
DRAWINGS (LEVEL): currently unknown
PROVISIONING TECH DOC: currently unknown
PMS: currently unknown
TECH REPAIR STDS: currently unknown
TEST PROCEDURES: currently unknown
SOFTWARE DOC: currently unknown

2.6 Computer Resource Support

The following resources will be used to maintain the computer hardware, firmware, and software to support program requirements.

NCSC personnel

2.6.1 Computer Hardware

Table 2-4

DESCRIPTION	LOCATION	NAVY STD/ COMMERCIAL	TADSTAND WAIVER	AVAIL/ TBD
IBM/Compatible	Org/Dep	Commercial		Available

Note: Computer use projected for program information held at NOMOADS project office, NCSC, Panama City, Florida

2.6.2 Computer Software

The following software is required to operate, test, and maintain the system.

==============================Table 2-5==============================

DESCRIPTION	MEDIUM	LOCATION	NAVY STD/ COMMERCIAL	TADSTAND WAIVER	AVAIL/ TBD
NOMOADS Program	Floppy	Org/Dep	Commercial		TBD

2.6.3 Life Cycle Support

The following activities have been assigned responsibility for life cycle support of computer resources:

Hardware: NOMOADS project office, NCSC, Panama City, Florida
Software: NOMOADS project office, NCSC, Panama City, Florida

2.6.4 Waiver Description

TADSTAND Waivers as described are required for the following equipments/software:

==============================Table 2-6==============================

ITEM	WAIVER DESCRIPTION
None at this time	

2.7 Facilities

The following unique facilities will be required at each maintenance level indicated.

::::::::::::::::::::::::::::::Table 2-7::::::::::::::::::::::::::::::

MAINT. LEVEL (O/I/D)	FACILITY DESCRIPTION
D	NOMOADS Depot Level Maintenance Facility, San Diego CA

2.8 Packaging, Handling, Storage and Transportation

2.8.1 Hazardous Materials

The following hazardous materials will be used:

High pressure oxygen in cylinders for the life support subsystem.

2.8.2 Packaging Specifications

The top packaging document and its compliance with MIL-E-17555 is described below:

Not determined at this time

Areas of non compliance are described below:

Not determined at this time

2.8.3 Unique PHS&T Constraints

Unique PHS&T constraints include:

NOMOADS will be packaged and shipped in a containerized fashion to maintain system integrity and avoid damage.

Storage suggestions include commercially manufactured container or modified Navy container.

2.9 Reliability, Maintainability, and Quality Assurance

The following system will be used to collect and analyze RMA data and correct deficiencies in meeting specification requirements:

Maintenance Data Collection System (MDCS)

2.10 Human Engineering

Unique human interfaces that will require special consideration for operation and maintenance of equipment are:

OPERATION:

Operator Height: 68 inches minimum, 74 inches maximum

Operator Weight: 150 lbs minimum, 210 lbs maximum

MAINTENANCE:

Caution: allergic skin reaction to castor oil used in system joints is possible.

SECTION 3.0

3.0 FLEET INTRODUCTION SCHEDULE

A schedule for installation of the system/equipment is provided below.

3.1 Navy School Introduction Schedule

The installation schedule for Navy Schools is provided in Table 3-1.

Table 3-1

ACTIVITY/SITE	INSTALLING ACTIVITY	DATE
NDSTC, Panama City, Florida	NDSTC, Panama City, Florida	FY93
NCSC, Panama City, Florida	NCSC, Panama City, Florida	FY93

3.2 Fleet Introduction Schedule

All ships which will use the new equipment and the method of fleet introduction, such as Ship Alteration (SHIPALT) or Ordnance Alteration (ORDALT) have been identified in Table 3-2.

Table 3-2

ACTIVITY/SHIP/SITE	METHOD OF INTRODUCTION (SHIPALT, ORDALT, ETC)	DATE
ARS (Salvage Ship)	SHIPALT	FY94
ASR (Submarine-rescue Ship)	SHIPALT	FY94
Mobile Dive Team, San Diego, CA		FY94

SECTION 4.0

4.0 ILS Organization

The ILS Management Team (ILSMT) members listed below have been assigned the responsibility for planning and executing ILS element tasks. Logistic Element Managers (LEMs) have not been listed except where performing as working members of the ILSMT.

Table 4-1

AREA OF RESPONSIBILITY	REP	ACTIVITY/CODE	A/V	COMMERCIAL
Program Manager	J. Granet	NAVSEA PMS395	222	(202)6922981
ILS Manager	NCSC	3430	436	(904)2344653
Maintenance Planning	NCSC	3430	436	(904)2344653
Manpower & Personnel				
Training & Devices	NDSTC	Training		
Supply Support	SPCC			
Support & Test Equip	NCSC	3430	436	(904)2344653
Tech Logistics Data	NCSC	3430	436	(904)2344653
Computer Resources	NCSC	3430	436	(904)2344653
Facilities				
Pckg/Handling/ Storage/Transp.				
Configuration Mgt	NCSC	3430	436	(904)2344653
Safety				
Reliability/ Maintainability/ Quality Assurance	NCSC	3430	436	(904)2344653
ISEA Representative	NCSC	3430	436	(904)2344653

SECTION 5.0

5.0 LIFE CYCLE COST

A life cycle cost plan in accordance with NAVSEANOTICE 4105 of 30 July 1984 is submitted under separate cover.

Not included as part of this thesis.

SECTION 6.0

6.0 MILESTONES

6.1 Major Program Events

Major program events have been tailored to this program and are listed in Table 6-1.

6.2 Milestones

Milestones for logistic elements and related programs have been tailored to this acquisition and are contained in Table 6-2. Not applicable milestones are indicated "NA" in Remarks column and explained in Appendix A.

6.3 Summary Chart of Major Logistic Milestones

A summary chart of selected major logistic milestones throughout the acquisition cycle of the system is attached as Table 6-3. Only significant events that apply to this program are presented.

TABLE 6-1. MAJOR PROGRAM EVENTS

PROGRAM: Navy One-Man One-Atmosphere Diving System		PROGRAM MANAGER: J. Granet		
PHASE	**MAJOR PROGRAM EVENT**	**SCHEDULED DATE**	**ACTUAL DATE**	**REMARKS**
Conceptual	D100 Conceptual Phase (Program Initiation)	82/10/01	82/10/01	
	D110 Complete Initiation Documentation			
	D120 Program Sponsor Authority to Start			
	D130 Complete Definition of Initial Support Concept			
	D140 Complete Definition of Development Options			
	D150 Select Alternative Concepts for D&V Phase			
	D160 Start Acquisition Review Process			
	D170 Milestone I Decision			
Demonstration & Validation (D&V)	D200 Demonstration and Validation (D&V) Phase	83/10/01	83/10/01	
	D210 Award Contract for Advanced Development Model (ADM)			
	D220 Complete Validation Testing			
	D230 Production Concept Selected	88/04/01		
	D240 Specifications for EDM Complete	88/06/01		
	D250 Start Acquisition Review Process	88/07/01		
	D260 Milestone II Decision	88/10/01		
Full Scale Development (FSD)	D300 Full Scale Development (FSD)	88/10/01		
	D310 Award Contract for Engineering Development Model (EDM)	89/10/01		
	D320 Start Factory Tests	90/10/01		
	D330 Start TECHEVAL	91/10/01		
	D340 Certification to Proceed to OPEVAL	92/04/01		
	D350 Complete OPEVAL	92/06/30		
	D360 Specifications for Production Complete	92/07/31		
	D370 Prepare for Acquisition Review Process	92/07/31		
	D380 Milestone III Decision	92/10/01		
Production/Deployment (P/D)	D400 Production/Deployment (P/D) Phase	92/10/01		
	D410 Award Production Contract	92/10/01		
	D420 Complete Follow-on Testing	94/09/30		
	D430 First Production Delivery (School)	93/07/31		
	D440 First Production Delivery (Ship)	93/09/30		
	D450 Material Support Date (MSD)	94/01/01		
	D460 Initial Operational Capability (IOC)	94/09/30		
	D470 Navy Support Date (NSD)	94/09/30		

APPENDIX B

NAVSEA ILSP-Draft

LIST OF ACRONYMS

ABL	Allocated Baseline
ACAT	Acquisition Category
ADM	Advanced Development Model
AEL	Allowance Equipage List
APL	Allowance Parts List
ATE	Automatic Test Equipment
Ao	Operational Availability
BITE	Built-In-Test-Equipment
CCCB	Component Configuration Control Board
CM	Configuration Management
CSA	Configuration Status Accounting
CSP	System Concept Paper
CTEA	Cost and Training Effectiveness
D&V	Demonstration and Validation
DCP	Decision Coordinating Paper
DFS	Direct Fleet Support
DID	Data Item Description
DOP	Designated Overhaul Point Development Option Paper
ECP	Engineering Change Proposal
EFR	Equipment Facility Requirements
ESS	Early Supply Support
FBL	Functional Baseline
FCA	Functional Configuration Audit
FMEA	Failure Modes and Effects Analysis
FSD	Full Scale Development

LIST OF ACRONYMS

GPETE	General Purpose Test Equipment
HEPP	Human Engineering Program Plan
HM&E	Hull, Mechanical, and Electrical
I&C	Installation and Checkout
IDS	Interface Design Specification
ILS	Integrated Logistics Support
ILSMT	Integrated Logistic Support Management Team
ILSP	Integrated Logistics Support Plan
IOC	Initial Operating Capability
IPS	Integrated Program Summary
ISEA	In Service Engineering Agent
JMSNS	Justification for Major System New Starts
LCC	Life Cycle Cost
LEM	Logistic Element Manager
LIST	Above is a list of milestone numbers that are dependent upon the one you are presently working with. You may wish to research these milestones using the remaining options in the previous screen. You may wish to print this screen.
LORA	Level of Repair Analysis
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
MAM	Maintenance Assist Module
MDT	Mean Down Time
MLDT	Mean Logistics Delay Time
MOA	Memoranda of Agreement
MSD	Material Support Date
MTBF	Mean Time Between Failure

LIST OF ACRONYMS

MTI	Mechanical Test Instrumentation
MTTR	Mean Time to Repair
NDCP	Navy Decision Coordinating Paper
NSD	Navy Support Date
NTP	Navy Training Plan
OLSS	Operational Logistic Support Summary
OPEVAL	Operational Evaluation
OR	Operational Requirements
PBL	Product Baseline
PCA	Physical Configuration Audit
PDD	Program Description Document
PDS	Program Design Specification
PEETE	Portable Electrical and Electronic Test Equipment
PHS&T	Packaging, Handling, Storage, and Transportation. PEIO
PM	Program Manager
PMS	Planned Maintenance System
PPBS	Planning, Programming, and Budgeting System
PR	Procurement Request
PRS	Provisioning Requirements Statement
PSMD	Preliminary Ships Manpower Document
PTD	Provisioning Technical Documentation
QA	Quality Asssurance
R&D	Research and Development
R&M	Reliability and Maintainability
RCM	Reliability Centered Maintenance

LIST OF ACRONYMS

RFP	Request for Proposal
S&TE	Support and Test Equipment
SEM	Standard Electronic Module
SM&R	Source, Maintenance, and Recoverability (Codes)
SMD	Ships Manpower Document
SPCC	Ship Parts Control Center
SPETE	Special Purpose Electronic Test Equipment
SSPP	System Safety Program Plan
SSR	Supply Support Request
T&E	Test and Evaluation
TECHEVAL	Technical Evaluation
TEMP	Test and Evaluation Master Plan
TM	Technical Manual Trademark
TMCR	Technical Manual Contract Requirements
TMOP	Technical Manual Outline Plan
TMP	Technical Manual Plan
TRS	Technical Repair Standards
TTE	Technical Training Equipment

APPENDIX C

NOMOADS DATA SHEETS

(Naval Coastal Systems Center, Panama City, Florida)

These data sheets are currently in use for NOMOADS diving operations at the Naval Coastal Systems Center in Panama City, Florida.

NOMADS DIVE LOG

DIVING OPERATIONS LOG

DATE ________________ SUIT NO. ________________

DIVE SUPERVISOR ____________________________

DIVE LOCATION ____________________________

TENDER(S) ____________________________

____

STANDBY DIVER ____________________________

COMMUNICATIONS ____________________________

OPERATOR ____________________________

DIVE NO. ____________

WATER DEPTH ____________

WATER TEMP ____________

VISIBILITY ____________

BOTTOM TYPE ____________

PURPOSE OF DIVE ____

____

TIME DOME SHUT ________________

TIME ENTERED WATER ________________

TIME REACHED BOTTOM ________________

TIME SURFACED ________________

TIME DOME OPENED ________________

TOTAL TIME OF DIVE ________________

SCRUBBER CANISTER TOTAL TIME......PORT _________ ______________________

STBD _________ Diving Supervisor

NOMADS DIVE LOG

TENDER PREDIVE CHECKOFF PROCEDURES

1. ALL "O" RING SEALS IN POSITION AND LIMBS CORRECTLY FITTED AND FULLY TOPPED OFF ______
2. INTENSIFIER TOPPED OFF AND ALL AIR BLED FROM THE SYSTEM ______
3. ALL JOINTS CORRECT AND FREE TO MOVE ______
4. REQUIRED MANIPULATORS FITTED AND CHECKED ______
5. CO_2 SCRUBBERS CHARGED AND CORRECTLY FITTED PORT ____ STBD ____
6. O_2 CYLINDERS CHARGED AND VALVES OPEN PORT Hi-PO_2 ____ STBD Hi-PO_2 ____
7. REDUCER-SHUTOFF VALVES OPERATIONAL AND SYSTEMS CHECKED FOR LEAKS PORT Lo-PO_2 ____ STBD Lo-PO_2 ____
8. O_2 CONTROLLERS OPERATING SATISFACTORILY AND ADJUSTED PORT ____ STBD ____
9. FRONT BALLAST WEIGHT FITTED & RELEASE MECHANISM FREE LBS. WT. ______
10. REAR BALLAST WEIGHT FITTED & RELEASE MECHANISM FREE LBS. WT. ______
11. BACKPACK FITTED AND SECURE ______
12. FLASHING BEACON FITTED AND SECURE ______
13. REAR BATTERY PACK CHARGED, FITTED PLUG GREASED, AND INTERIOR LIGHT OPERATIONAL ______
14. COMMUNICATIONS/LIFTING CABLE CORRECTLY FITTED ______
15. CABLE JETTISON SYSTEM SATISFACTORILY ______
16. O_2 MONITOR FUNCTIONING SATISFACTORILY AND STABILIZED AT 21% ______
17. CABIN PRESSURE GAUGE ADJUSTED TO READ 0 ______
18. SUIT INTERIOR, DOME, AND SEATING RING CLEAN AND DRY ______
19. LATCHING MECHANISMS OPERATE FREELY ______
20. CO_2 CHANGEOVER VALVE CLEAN AND DRY AND OPERABLE ______
21. THROUGH WATER AND HARDWIRE COMMUNICATION SYSTEMS CHECKED ______

COMMENTS:

Signature: ______

Date: ______ Time: ______

(over for operator)

NOMADS DIVE LOG

OPERATOR PREDIVE CHECKOFF PROCEDURES

PURPOSE OF DIVE: ______________________________

DURATION OF DIVE: ______________________________

1. O_2 BOTTLE VALVES OPEN PORT: ______ STBD: ______

2. STARBOARD LIFE SUPPORT SYSTEM CHECKED SATISFACTORILY AND REDUCER-SHUTOFF VALVE CLOSED. Hi-PO_2 ______ Lo-PO_2 ______

3. PORT LIFE SUPPORT SYSTEM CHECKED SATISFACTORILY AND SYSTEM OPERATIONAL. Hi-PO_2 ______ Lo-PO_2 ______

4. FACE MASK, VALVES, TUBES, FITTINGS, COUPLINGS CORRECTLY FITTED AND OPERATING SATISFACTORILY. MASK WIPED OUT WITH ALCOHOL. MICROPHONE PLUGGED INTO THE PORT PANEL. Inhale ______ Exhale ______

5. O_2 MONITOR STABILIZED AT 21%. ______

6. CABIN PRESSURE GAUGE ADJUSTED TO READ 0. ______

7. CHECK INTERNAL LIGHT ______

8. BACKPACK COVER FITTED AND SECURE ______

9. EMERGENCY LIFTING POINT SATISFACTORY ______

10. BALLAST JETTISON SYSTEMS FREE TO BE OBERATED FRONT WT: ______ REAR WT: ______

11. COMBINED COMMUNICATION AND LIFTING CABLE JETTISON SYSTEM FREE ______

12. COMMUNICATIONS SYSTEMS SATISFACTORY HARD LINE ______ THRU WATER (BATT TEST) ______

13. THRU' WATER TRANSDUCER DEPLOYED ______

14. FLASHING BEACON ACTIVATED ______

15. SUIT CLEAN AND DRY AND READY TO ENTER ______

16. DOME AND SEATING RING CLEAN AND READY TO CLOSE ______

17. OPERATOR READY TO DIVE ______

COMMENTS:

Signature: ______________________

Date: ____________ Time: ________

(over for maintenance)

NOMADS DIVE LOG

LIFE SUPPORT

DATE ____________

OPERATOR ____________________

TIME	$O_2\%$	CABIN PRESSURE	PORT		STBD		CABIN TEMP
			HPO_2	LPO_2	HPO_2	LPO_2	

Signature: ____________________
Record Keeper

NOMADS DIVE LOG

DIVE DATA

TASK PERFORMED: ______________________________

____

____

OPERATOR COMMENTS: ______________________________

____

____

GENERAL COMMENTS: ______________________________

____

____

REPAIRS MADE OR REQUIRED: ______________________________

____

____

SIGNATURE OF PROJECT ENGINEER ______________________________

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